The Geology of Rangiawhia Peninsula, Doubtless Bay, North Auckland.

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Abstract.

Basic pillow lavas, submarine keratophyres and associated sediments (late Palaeozoic or early Mesozoic) are overlain unconformably by breccia, conglomerate and sandstone (perhaps upper Cretaceous). Folding about east-west axes has bent these sediments vertical. After the folding, tear faults striking north-west have displaced the country north-east of the fractures north-westwards at least 2¼ miles. With this movement, a dyke-like mass of basic and intermediate plutonic rocks was intruded along the plane of weakness for over 70 miles, from North Cape to south of Whangaroa Harbour.

There is a marine terrace just over 100ft. above sea level and one at 50ft.

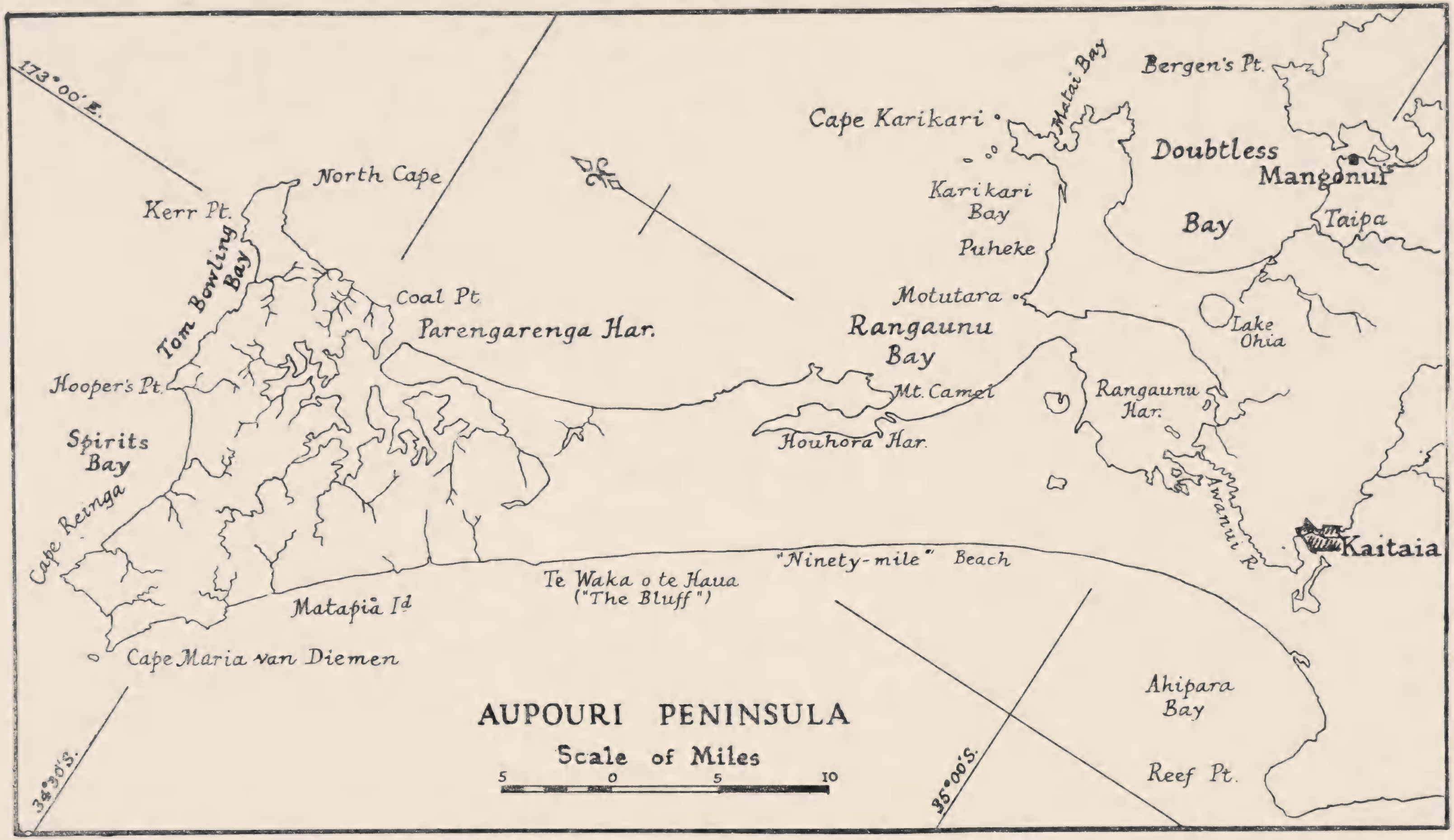
INTRODUCTION.

The northernmost part of New Zealand is comprised of a group of high, rocky tracts linked together and joined to the "mainland" by belts of sand hills, of which the chief is that joining the North Cape-Cape Reinga highland (itself consisting of several smaller blocks linked by sand dunes), Te Waka o te Haua ("The Bluff"), and Mt. Camel to the high ground near Kaitaia. This region Bell and Clarke (1910) designated the Aupouri Peninsula, from the name of the Maori tribe that formerly flourished upon it (text-fig. 1). It is a region of distinctive geographical and geological character, comprising massifs that, though strictly part of the mainland, present themselves irresistibly to the mind in the character of islands—an effect to which the topography and their isolation are contributory.

Rangiawhia Peninsula* is a land-tied island forming the promontory that separates Doubtless Bay on the east from Rangaunu Bay on the west, at the southern end of the great tombolo leading to North Cape. The rocky part of the Peninsula (plate 5) rises to a height of 600 feet above the sea and has rather the shape of a hand with one extended finger pointing to the north. It is 7 miles long from north to south and 5 miles from east to west, with an area of 15 square miles and is joined to the mainland by a belt of sand dunes and swampy ground some 3 miles wide and 8 miles long, in which some of the dunes rise to heights of more than 100 feet. This tombolo serves also to link together the conical rocky hill Puheke and the low-lying rocks around Rangiputa, both to the west of the Rangiawhia block.

The geology of this area has received but cursory treatment from earlier geologists, probably because of its relative inaccessibility. Hector (1891, p. lxxxi) visited a copper deposit on the south face of Knuckle

* Sometimes called Cape Karikari Peninsula, from the name of its northernmost promontory



Text-fig. 1. Locality map of northern North Auckland.

Point that had been prospected in 1847*, and published an interesting sketch of the cliff-face there. On McKay's map of 1894 the area is marked as composed of Palaeozoic sediments and igneous rocks, the boundary between solid and drift being delineated. Bell and Clarke (1910), following McKay (1894, pp. 72, 89, 90) and Marshall (1908, p. 81), map the rocks as falling in their Older Igneous Group. Apparently neither they, nor Marshall, actually visited Rangiawhia Peninsula.

The rocks of the Peninsula may be grouped as follows (see also plate 5):

5. Drifts
   - (c) Recent alluvium
   - (b) Sand dunes
   - (a) Elevated marine sands

4. Basic and Intermediate intrusives. Dykes, mainly of intermediate nature, invade the older rocks throughout the Peninsula; but they become more numerous and more massive to the east, giving place, about Whangatupere Bay and in Cape Karikari to the north-west, to a continuous mass of coarse-grained igneous rock of a banded nature which includes thoroughly basic and even ultrabasic types.

3. Breccias, conglomerates, grits and sandstones, appearing as a narrow strip along the south-east coast of the Peninsula, between Whatuwhiwhi and Knuckle Point.

2. Hard black shales of uncertain stratigraphic position. They have so far been found only in the same places as rocks of Group 3. They lie to seaward of the breccias, conglomerates and sandstones and are faulted against them, generally below high tide mark.

1. Acid and basic soda-rich submarine lavas, including pillow lavas, with some associated sediments, underlying most of the southwestern part of the Rangiawhia Block.

GROUP 1.—THE LAVAS AND THEIR ASSOCIATED SEDIMENTS.

Distribution.

Rocks of this Group underlie all that part of the Peninsula extending eastwards and north-eastwards from the northern end of Tokerau Beach to beyond Brodie's Creek, and inland to the northern side of the belt of high ground called the Te Ari Ridge that runs east and west between Whatuwhiwhi and the village of Merita, except for a narrow coastal strip north-east of Whatuwhiwhi where beds of Groups 2 and 3 occur. Excellent outcrops occur along the coast, but the rocks along the ridge are in general much weathered and the slopes of the ridge south of Merita are mantled with sands to a height of about 200 feet. Rocks of this group also occur along the crests of the ridges leading to Knuckle Point and Pihakoa Point, where they form remnants of the roof of

* Hector writes that the prospecting was done in 1857, but the Rev. Wm. Puckey, who was a missionary at Kaitaia, records in his journal having visited the Brodies at Knuckle Point, whence they had gone to open a copper mine, on 22nd March, 1847.

the intrusion of basic and intermediate rocks. Maitai Pa, in the centre of Matai Bay*, is also composed largely of them, and they also outcrop, surrounded by intrusive rocks, inside the north head of Matai Bay.

The rocks of the Group exhibit some variety, and the work so far carried out permits the recognition of three subdivisions, namely:

(c) Light-coloured acid lavas, including keratophyres and quartz-keratophyres;

(b) Dark-coloured basic lavas often variolitic and sometimes showing pillow structure;

(a) Indurated sandstones and argillites.

(a) *Argillites and greywackes.* At the northern end of Tokerau Beach, interstratified argillites and greywackes in beds one inch to eight inches in thickness outcrop at the base of the cliffs and extend around the headland to the beach Perehipe†. The dip wavers in both direction and amount, but in general it is east-north-east at about 30°. The beds are disturbed by a number of small faults and broken by closely-spaced joints running north-west by west and north-north-east. They are overlain with apparent conformity by dark lavas of subdivision (b). A thin sill-like mass of lava was seen near the top of the stratified rocks.

In a bluff near the middle of the beach Perehipe thin-bedded argillite and greywacke is followed upward by lava with quartz amygdales up to 2cm. across and dense greenish variolite 3 feet thick. Hard, splintery greywacke and argillite follow in relatively thick beds much broken by small dislocations; the strata are thinner (about 6 inches thick) higher up in the succession. A small reversed fault dipping 43° to the north-east displaces the beds about 12 feet.

At the eastern end of the beach there is a small outcrop of the thin-bedded sediments, with wavy but generally horizontal stratification. These beds meet white-weathering keratophyre on their northern side in a vertical contact running east by north. The keratophyre sends small apophyses amongst brecciated wisps of the sediment and has perhaps slightly hardened it. On the southern side of the exposure the sediments pass beneath a breccia of keratophyre, some greenish, streaky crushed lava and argillite fragments. The way in which argillite is mingled with keratophyre in the headland east of Perehipe will be described below.

The greywackes and argillites make their next appearance at Knuckle Point, the easternmost point of the Peninsula. They occur low in the cliffs on the northern side of the promontory, dipping south-west at a moderate angle. Greywacke is here more prominent than argillite, and though the rocks are in part thin-bedded, as at Tokerau Beach, more massive strata also occur. The sediments are closely associated with fine-grained dark-coloured lavas, but the relationship of the two rock types is not well shown. By analogy with the sequence near Tokerau Beach, it may be presumed that they are interstratified.

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* This is commonly spoken of as Merita Bay. The rocky knoll in the centre of the bay is known to the Maori people as Maitai, and this name, corrupted to Matai Bay, is applied to the whole bay on all the available maps and charts.

† For convenience of description a number of Maori place-names, kindly furnished by local residents, will be used. The localities so named are marked on the maps.

Along the crest of the Knuckle Point ridge and high on its southern slope, thin-bedded greywackes and argillites are weathered to pink and white banded clays and dip south-west and west at angles of about 25°. These must be the "pink tuffstones" shown in Hector's sketch (1891, p. lxxxi), for they are conspicuous above and to the east of the green coloration on the cliff face, which presumably marks the site of the copper prospect. I did not see the sharp synclinal fold shown in the sketch, but this may well be visible from seaward.

The attitude of the beds at Knuckle Point seems to be due to movements associated with the intrusion of closely-spaced dykes, trending north-westward and connected with the Whangatupere Bay intrusion.

At Pihakoa Point, and south of it, there are small areas of indurated fine and very fine sandstone with splintery or conchoidal fracture showing small scale lamination on fresh surfaces. They are in more massive beds than the rocks at Tokerau Beach but resemble some of those at Knuckle Point. As at Knuckle Point, their relations to associated lavas are not clear. A poorly-defined lamination strikes north-west and dips at about 50° to the north-east. The influence of the numerous dykes sent off from the Whangatupere Bay intrusive is again manifested in the attitude and distribution of the strata. The roof rocks of the intrusive have a strong north-west grain.

(b) *Basic lavas.* At the northern end of Tokerau Beach, and in the bluff near the middle of Perehipe Beach, basic lavas, exposed for only 18 feet above their base, succeed the argillites and greywackes with apparent conformity. In two places the lavas and sediments are interstratified over a small part of the sequence at their junction. The lavas are dark-green and variolitic with quartz-filled amygdales up to 2cm. across in parts and patches of cavernous rusty calcite near the base. Glassy material is not conspicuous, but pillow structure can be recognized, on close examination, in the cliff face at the western end of Perehipe Beach: the individual pillows are flattened and dip north-east at about 20° in approximate conformity with the underlying sediments.

Some 3½ miles to the north-east, greenish to dark-grey variolitic lavas with associated black perlitic glass outcrop on both sides of the entrance to Brodie's Creek. They show pillow form on the eastern side of the inlet and along the coast between 300 and 600 yards west-south-west of its entrance. The pillows are well preserved at the westernmost part of this exposure, where their elongation indicates that the mass has been tilted 66° to south by west: the mutually accommodating curves of the pillows suggest no overturning (plate 1, fig. 1).

The lower part of the succession is best studied on the eastern side of Brodie's Creek. Dark, fine-grained lava appears just within the mouth of the inlet and is followed to the south by 18 feet of fine-grained dove-grey sandstone with current bedding, 12 inches of dark lava and further laminated sandstones. The contacts between lava and sediment dip 76° north-west by north. The sandstone, which is crossed by microscopic veins of albitic plagioclase, passes south into a grey-white flinty rock with an orange-brown to reddish weathering crust, crossed by narrow quartz veins and cracks filled with epidote. The lamination of the sediment gradually disappears as it assumes its new character.

The resulting rock, which extends to the opposite (western) head of the inlet, has lost almost all signs of clastic origin and is composed of a mosaic of feldspathic material with scattered quartz grains and little flakes of biotite. It appears to be a kind of adinole.

The section at Brodie's Creek is then interrupted for 50 yards by a little beach. south-south-west of which sediment gives place to lava along a plane dipping 52° north-north-west. The lava, which shows good pillow form, continues for about 75 yards and is succeeded south-south-eastwards, along a plane dipping 70° north-north-east, by a body of white-weathering lava which extends for at least 100 yards farther. Beyond this the coast has not yet been examined.

I think that this section, with its steep northward dips, may be overturned. No definite evidence on the point was obtained, though the current bedding in the sandstone may be expected to yield it to more minute study. Nevertheless, the succession west-south-west of Brodie's Creek, which will be described below, where the beds dip south or south-east, suggests that the beds south of the pillow lavas are the younger, and at Tokerau Beach interstratification of lavas and sediments characterizes the base of the succession.

About 450 or 500 feet of lava and sediment is exposed in the section on the eastern side of Brodie's Creek, which is terminated northward by a mass of later intrusive rock. A little over 400 feet of lava appears where the coast cuts across the strike 600 yards west-south-west of the mouth of the creek, but this second section probably does not extend so far down in the succession as the first, for the thick bands of sediment do not appear in it north of the pillow lavas.

There are some points of difference between the succession incorporating the basic lavas at Brodie's Creek and that at Tokerau Beach. The thin-bedded argillites and greywackes exposed at Tokerau are not to be seen at Brodie's, where intrusive rock limits the section on the north. As has been mentioned, however, such sediments reappear at Knuckle Point. The sandstones interstratified with the lavas at Brodie's Creek are unlike any exposed at Tokerau Beach. At Brodie's Creek the lavas themselves seem much fresher and the pillow form is much better preserved than at Tokerau Beach. In spite of these differences, however, it seems justifiable to correlate the basic lavas of these two localities, not only on lithological grounds but also on structural evidence to be given below in connection with the rocks of Group 3.

(c) *Keratophyres.* The keratophyres and quartz-keratophyres are green to light-grey, weathering white, often with amygdales of chalcedony and quartz and commonly porphyritic, though the phenocrysts are sparse. The silica of the amygdales is sometimes stained red, while the plagioclase phenocrysts may be pink, and these, set in the green base of a fresh lava, make a handsome rock. The amygdales often stand out prominently on weathered surfaces, but otherwise the weathered rock is buff or dirty-white, perhaps with flecks of green, and often earthy in appearance. Carious erosion of surfaces of quite fresh rock is common along the coast.

Throughout the keratophyres are discontinuous, often ill-defined bands of light-coloured porphyritic rock streaked with bright-green chlorite in flattened wisps and ragged ribbons, arranged with their broad surfaces parallel so as to impart a foliation to the rock, along which it shows a rude fissility. The largest mass of this green streaky rock seen is in the cliffs below the schoolmaster's house at Whatuwhiwhi, where it outcrops for over 200 yards in the cliffs. The flowing wisps of chlorite give a lively impression of movement, and I believe that the bands of green streaky rock represent crush zones along which adjustment has taken place during the strong folding movements that have affected the relatively rigid lavas. So far, no order has been discovered in their distribution and disposition.

As has been mentioned (p. 38), quartz-keratophyre meets thin-bedded argillite and greywacke in a partly intrusive contact trending east by north at the eastern end of Perehipe Beach. Thence the kerato-phyres in their different varieties outcrop eastwards along the coast to Waiari; beyond this, they appear discontinuously in the cliffs north-eastwards for about a mile, their exposure being interrupted by the development of breccia, conglomerate and sandstone beds of Group 3.

There is a good deal of argillite interstratified with keratophyre and greenish crush rock between tide marks at the tip of the headland east of Perehipe Beach, its amount decreasing towards high-water mark. The planes of junction between sediment and lava dip north-north-east at 70°. Farther east, argillite is enclosed in the lava in such a way as to give the appearance of a breccia. In places the argillite fragments are only an inch or so across, but some large masses occur. The planes of junction between the larger argillite masses and the lava strike, generally, east and west, with varying dips, sometimes southerly and sometimes northerly. Not very much reliance can be placed on the attitudes of the argillite masses, for it is quite likely that they were displaced during the extrusion and possibly partly intrusive emplacement of the keratophyre. The relationships here are reminiscent of those described by Cox (1915, p. 308) from Pembrokeshire, where, he believed, the rocks "represent what were practically lavas which burrowed among the mud of the sea-flood" and that "at times, the escaping vapours completely fractured the almost solidified rock, converting it into a breccia." He found intermingling of sediment and lava at both bottoms and tops of flows. At Rangiawhia the presence of the argillite probably indicates either the top or the bottom of a flow, but the exposure is too limited to show which it is.

At Waiari a hard breccia of dark, angular keratophyre fragments, up to 1½ inches across, set in a grey-white matrix of micro-crystalline quartz and muddy material, forms a low bluff to the west of the stream that discharges there. This is regarded as an agglomerate formed by explosions connected with the effusion of the keratophyre. It is succeeded southward by a sheeted zone with fractures striking N.60°W., in which greenish crush rock penetrates the breccia in so intimate a fashion as to suggest that it represents the alteration product of kerato-phyre, here intrusive into the breccia before its cementation. Chloritic keratophyre showing conspicuous carious weathering succeeds the sheeted zone to seaward. This belt of fracture is probably connected with the zone of green crush rock below the schoolmaster's house at Whatuwhiwhi, which lies on the line of strike of the fractures and is itself broken by master joints trending N.60°W. and dipping south-westward at 85°.

The dark-coloured pillow lavas 600 yards west-south-west of Brodie's Creek give place southwards along the coast to light-coloured porphyritic amygdaloidal keratophyres, which have a prominent wide-spaced parting, taken as bedding, that dips south-eastwards at about 40°. Though quite distinct from the usual type of pillow-forming lava, these rocks have shreds and streaks of glass associated with them and are definitely pillowy in places. They outcrop continuously, save for interruption by dykes, for about 700 yards along the coast, to their contact with breccia and conglomerate beds in a headland 1,100 yards south-west of the entrance to Brodie's Creek.

The apparent thickness of the keratophyres in this section is a little more than 1,000 feet, but this value is possibly greater than the true thickness, for, as will be shown later, tear faults striking north-west have allowed north-westward movement of the country on the north-eastern sides of the fractures at short intervals along this coast. These faults are difficult to detect in the lavas and have only been demonstrated where the stratified rocks of Group 3 are exposed, but they undoubtedly transect the lavas just as frequently, and may have caused repetition of part of the keratophyre sequence.

Inland, keratophyres outcrop in the Te Ari Ridge running east and west between Whatuwhiwhi and Merita; in general the rocks are much weathered, but fresh amygdaloidal keratophyre outcrops in the knoll east of the Whatuwhiwhi-Merita Track where it crosses the ridge.

The lavas that form remnants of the roof of the intrusive mass of Whangatupere Bay, along the ridge between Koware trig. station and Pihakoa Point, prove under the microscope to be thermally metamorphosed representatives of the keratophyre group. In hand specimen they are quite different from the rocks of the southern coast of the Rangiawhia Block, being dense, dark-grey and splintery, and to be distinguished only with difficulty, under the lens, from the indurated greywackes with which they are associated. The same is true of the lavas surrounded by intrusive rocks in the north-western corner of Matai Bay.

Structure, correlation and age.

On the whole, little direct evidence on the structure has been gleaned from the outcrops of the rocks of Group 1. Observations on their contact with argillite and greywacke and on planes taken to represent bedding in the lavas suggest that, between Perehipe and Waiari, they strike roughly east and west. The dip is variable, either northward or southward, steep or moderate. Around Brodie's Creek, too, the strike varies about the east-and-west direction, though in the keratophyres south-west of the inlet it swings to north-east. The beds dip steeply northward east of the inlet and southward or south-eastward at steep to moderate angles south-west of it.

From the study of the breccias, conglomerates and sandstones of Group 3, it is clear that the country has been subjected to vigorous folding about east-and-west axes and, in so far as they were capable of yielding by flexure, the lavas must have partaken of this deformation.

Since these rocks are rather rigid, probably some of the adjustment took place by fracture and crushing. It is not possible to attempt to reconstruct the attitude of the lavas before this folding.

Since the folding, the area has been broken by tear faults striking north-west, the results of which will be more conveniently considered below in connection with the structure of the beds of Group 3. Here it may be mentioned that there is some evidence that the pillow lavas near Tokerau Beach and those near Brodie's Creek are at the same horizon and once formed a belt striking about east-and-west that has been disrupted and displaced by the tear faults (text-fig. 3, p. 49).

So far, no fossils have been found in Rangiawhia Peninsula to fix the age of any of the rocks there. The nature and sequence of the lavas invite direct comparison with those discovered on Great Island, in the Three Kings Group, by Bartrum (1936 a & b). He found spilitic pillow lavas 40 feet thick at the base of the cliffs in North West Bay, associated with greywackes showing fine lamination in places and hard black shales, while albite porphyry*, estimated as 60 feet thick, outcrops high above in the cliffs, and quartz-keratophyre lava (perhaps partly tuffaceous) is recorded from surface blocks above the porphyry.

We have here a section strictly comparable, even in detail, with that at Rangiawhia Peninsula. Lamination of the greywackes is characteristic of both areas, while Bartrum's description of the pillow lavas is applicable in all points to those near Tokerau Beach. I have not been able to visit these pillow lavas near sea level at the north-west landing on Great Island, but the overlying keratophyres, whether they be intrusive or extrusive, are comparable, both in appearance in the field and under the microscope, with types from Rangiawhia Peninsula. It may be remarked that the albite porphyry of Great Island is richly amygdaloidal in places, while little, if any, sedimentary rock intervenes between its outcrop and that of the rocks described by Bartrum as lavas higher up the cliffs, though unfortunately talus obscures the accessible ground. Its character as a sill can therefore not be regarded as above question; it may well be part of a group of lava flows. It is remarkable that even the tuffaceous rock (Bartrum, 1936a, p. 416) finds its counterpart in the brecciated keratophyre at Waiari.

There can be little doubt that the rocks of these two areas, 85 miles apart, belong to the same formation.

Bartrum believed that the rocks of Great Island belong "to the Hokonui System . . . approximately mid-Mesozoic in age . . ." (1936a, p. 415) and correlated them with lavas interbedded in the Waipapa Series of Bell and Clarke (1909) around Whangaroa. The recent discovery by the Geological Survey† of fusilines and corals in a marble associated with pillow lavas, in the Waipapa Series near Whangaroa, proves that this part of the Series is of Permian age, so that possibly both the Great Island rocks and those of Group 1 in Rangiawhia Peninsula are also as old as this.

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* Intrusive keratophyre in the terminology of Wells (1922).

† Personal communication from Dr. J. Marwick.

Bartrum specifically observed that the Great Island igneous rocks are not to be regarded as the magmatic associates of the Upper Cretaceous pillow lavas near Cape Maria van Diemen, but are older; "their period of eruption is separated from that of the lavas of the mainland by one of the greatest unconformities yet established in New Zealand" (1936a, p. 422). Specimens of lava collected from South West Island and Hole-in-the-Wall Rock (one of the Princes Islets) by Buddle and Johnston in 1947 were classified by Bartrum as quartz andesites resembling members of the Upper Cretaceous (Rahia) Series of the area around Cape Maria van Diemen, to which formation he assigned them (Bartrum, 1948, p. 206). Since the rocks of the North Cape-Cape Reinga area known as the Older Volcanic (or Whangakea) Series (Bell and Clarke, 1910; Bartrum and Turner, 1928) have been transferred to the Upper Cretaceous (or Rahia) Series (Bartrum, 1934), Great Island has been the sole remaining bastion of supposedly pre-Cretaceous rocks in the Far North.

To return to Doubtless Bay, there is a belt of basic submarine lavas with pillow structure which forms the headlands along the southern shore of the Bay, 8 miles south of the Rangiawhia Block, from Mangonui Township at least to the promontory west of Taipa Beach. Inland of these, in Taipa Estuary, are Cretaceous sediments striking east-and-west and dipping northwards at moderate to steep angles, which closely approach the lavas on the east side of the Estuary, but are not to be seen actually in contact with them. Green cherts occupy the interstices between the pillows, and discontinuous bands of red and green chert are caught up in the lavas. The largest mass of sediments seen in the lava is at the western end of Taipa Beach, where the included and partly invaded sedimentary beds strike south-west by west. Because of the close association of the sedimentary beds with the lavas and their general conformity of strike, it seems very likely that these lavas are part of the Upper Cretaceous succession here. Besides, pillow lavas are well known to be associated with Cretaceous and Eocene beds in many other parts of North Auckland.

There are no keratophyres between Mangonui and Taipa, however, and the sediments associated with the pillow lavas are quite different from those in Rangiawhia Peninsula. Moreover, while the lavas between Mangonui and Taipa are freely invaded by a medium to coarse-grained albite diorite, which is probably as abundant as the pillow lavas in the coastal outcrops, no such intrusive appears in Rangiawhia Peninsula.

For these reasons, admittedly not highly satisfactory, I am inclined to think that the lavas of Group 1 at Rangiawhia are not properly to be correlated with those of the southern shore of Doubtless Bay, but are more probably pre-Cretaceous.

The question whether they are coeval with the Palaeozoic members of the Waipapa Series at Whangaroa, mentioned above, must be left in abeyance until fossils are found, or until more is known of the successions and rock types in areas where there is fossil evidence of age.

GROUPS 2 & 3.—SHALE GROUP AND BRECCIA, CONGLOMERATE AND SANDSTONE GROUP.

These two groups of rocks are exposed in close association along the same stretch of coast and it is convenient to consider them together, with the aid of a large scale map (plate 4).

Distribution.

Breccias, conglomerates and sandstones of Group 3 outcrop as a narrow, interrupted strip along the coast between Waiari and Brodie's Creek and again, apparently, at the old copper workings on the southern side of Knuckle Point. I have not yet visited this last locality, but Hector (1891, p. lxxxi) describes the deposit, which he regarded as a volcanic agglomerate, as being the country of the copper-ore and his sketch of the cliff shows that an excellent exposure of the junction between the breccia and the older lavas is there available. This contact has been examined on the coast at a point 1,100 yards south-west of the mouth of Brodie's Creek as well as in the area described in detail below.

The accompanying map (plate 4) represents the relationships of the formation for a distance of about a mile east-north-eastward from Waiari. The strip of rocks of Group 3 is nowhere exposed for a width of more than 150 yards and its greatest inferred breadth is only 300 yards. Marine erosion has to proceed but little farther to remove the members of the Group altogether. The waves have, in many places, worn away the land until the resistant lavas have been reached, so that the rocks of Group 3 are exposed chiefly in the low tide platform, though also in the cliffs in some places (plate 2, figs. 1, 2). They strike steadily east and west (save for a slight systematic curving due to faulting), everywhere stand very steeply and are often overturned to the south (plate 2, fig. 2).

Close to their contact with the lavas the breccias are very coarse and contain masses, several feet across, of greenish crushed lava, normal keratophyre and dark grey, indurated, fine sandstone. On the eastern side of the point at Waiari they contain large boulders of graphic granodiorite (plate 2, fig. 3) of which no parent mass is now exposed*. The majority of the smaller blocks and pebbles are of keratophyre. Other constituents are spotted greywacke that has undergone mild thermal metamorphism, coarse sandstone and pieces of an older conglomerate. Much of the coarser material is angular, but a fair proportion of well-rounded boulders and pebbles is present. Generally speaking, the material of the breccias and conglomerates becomes finer upwards in the sequence and gives place to fine conglomerates, grits and sandstones.

These characteristics of the beds and their distribution suggest that the group represents the basal part of a normal marine sequence

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* It may be recalled that smaller pebbles of granitic rocks occur in basal conglomerates of the Kaeo formation in the Whangaroa district (Bell and Clarke, 1909, p. 50).

deposited unconformably upon the lavas of Group 1, rather than a volcanic agglomerate as Hector supposed. The great size and angular form of many of the boulders make it clear that the land from which the fragments were derived was very close to the area where the deposits lie—some of the breccias, in fact, look like cliff-foot talus accumulations.

The basal contact of the breccias with the lavas is well exposed in a few places, but, since the beds stand at high angles and are overturned in many places at the contact with the relatively unyielding lavas, the junction may be expected to have been a plane of movement and, as such, is not capable of affording much information about the original nature of the surface on which deposition took place. Later faulting has also occurred along lines crossing the contact. The possibility of the generation of independent zones of breccia by both kinds of movement cannot be disregarded, although the actual lines of such brecciation would be difficult to detect in the field. The magma of the injected series (Group 4) has taken advantage of the contact as an easy route of uprise in a number of places.

Between half a mile and a mile north-east of Waiari the beds of Group 3 are limited to seaward by a fault striking parallel to the coast, generally between tide marks, which brings the breccias, conglomerates and sandstones into contact with hard, coal-black slaty shales, the parting in which strikes slightly oblique to the fault-line and generally dips south-east at about 60°. These shales reappear at the extreme edge of the low-tide platform south-south-east of the cliffs at Waiari. Small pebbles of shale along the beach just east of the schoolmaster's house at Whatuwhiwhi suggest that the shale is not far off shore farther to the south-west.

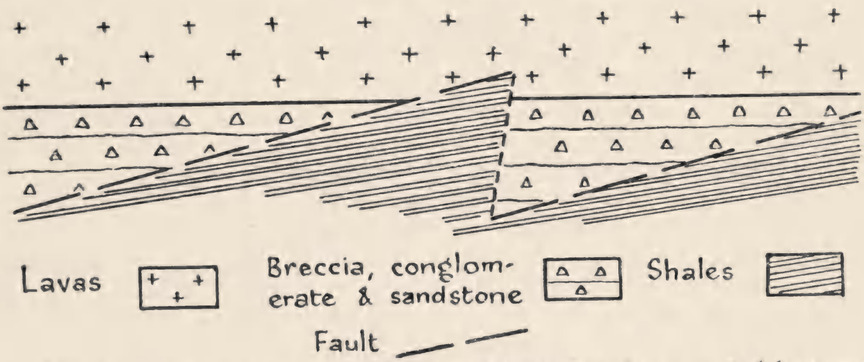
Several sills intrude the shales and they are crossed also by dykes, both kinds of intrusion being representatives of Group 4 (plate 3, figs. 2, 3).

Only for a distance of 40 yards about 200 yards north-east of Homarere, have the shales been seen in contact with the lavas of Group 1. Here, though the contact is poorly exposed, the shale seems to be faulted against the lavas along a plane striking roughly parallel to the fault separating the shales from Group 3 beds elsewhere, and dipping north-west at 63°.

Structure.

As the beds are followed north-eastwards from Waiari, the east-and-west trending contact of the breccias with the lavas is found to be progressively displaced to the north by a series of tear faults striking north-north-west. The movement of the country to the north-north-west or north-west on the north-eastern sides of these faults is well displayed by the displacements of the fault plane separating the black shales from the breccias, conglomerates and sandstones, and as can be seen from the mapping, the effects of drag along the faults is clearly exhibited in the curving of the strike of the beds of the breccia-sandstone group as well as in that of the black shales at Homarere.

In only two cases is the apparent relative displacement along the faults in the opposite sense and in only one case is this appearance truthful—that is, in the case of a reverse shift of 20 yards near Anaputa. The second apparent case, where the shales meet the lavas 200 yards north-east of Homarere, is due to a different cause. It will be seen that the fault that separates the shales (Group 2) from the breccias, etc., of Group 3 strikes obliquely to the east-and-west contact between beds of Group 3 and lavas of Group 1. If we restore the beds to their original position, before the north-north-west shifting took place, we find that the trend of the fault must have caused it to approach ever nearer to the breccia-lava contact as this contact was followed eastward, until it crossed the boundary at a point that now lies 200 yards north-east of Homarere (Grid position 92219838). Movement along the fault promptly died out as the plane passed into the infrangible lavas and the displacement was taken up by another plane of the same trend in the more readily broken beds of Group 3 (text fig. 2). The trend of the



Text-fig. 2. Diagram showing relations of shales to breccia group and lava group north-east of Waiari.

new fault plane, however, still brings it continually nearer the breccia-lava contact eastwards, and it must encounter the lavas again at a point that now lies immediately north-east of the area mapped in detail. I hope that its behaviour on doing so will be observable here when the mapping is extended farther north-eastwards, though igneous intrusion, the trend of the coast and the rugged cliffs together seem to militate against it.

Before the wider implications of this tectonic pattern are discussed, another point in connection with the map (plate 4) may be mentioned. Faults are difficult to detect in the lavas and in the jumbled mass of the lower part of the breccia. Four faults not observed seem necessary to explain the distribution of the beds. Three of these have been drawn in accordance with the north-west or north-north-west grain of the country so clearly seen in the disposition of dykes and joints, other faults, and in the coastal morphology. The fourth, at Homarere, has been drawn with a north-north-eastward trend, on the basis of the positions of lava outcrops protruding through the beach gravels, and of a mass of shale exposed a few dozen yards off-shore at low water, supported by the presence of a prominent cleft in the lavas in the cliffs and the position of a small outcrop of breccia. Although this trend is tectonically inharmonious, I have preferred not to multiply assumptions in order to dispense with it, for the observed fault plane at Waiari shows that divergences from the general trend do occur. Obvious difficulties arise, however, in the area indicated by the question-mark. Further observation will probably show some deficiency in the mapping here.

When the style of tectonics found north-east of Waiari is applied in explanation of the distribution of all the outcrops of Group 3 beds so far known, including that described by Hector at the copper mine, we find that, across a belt of country of a width of nearly 3¼ miles at right angles to the planes of movement (taken as trending about N.40°W.), the base of the breccias has been shifted north-westwards a total distance of over 2¼ miles. In the outcrops that I have myself examined, of which the most north-easterly is that 1,100 yards south-west of Brodie's Creek, there has been a north-westward shift of 1,650 yards distributed over a distance of 2,270 yards normal to the direction of movement*.

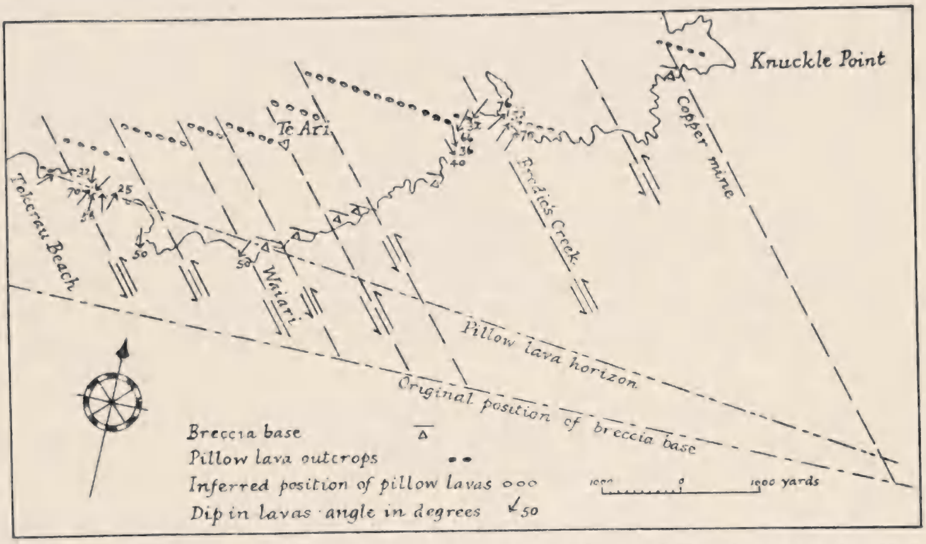
This displacement is probably connected with the intrusion of the Whangatupere Bay basic igneous mass, or rather, the intrusion, which appears to connect with similar rocks at North Cape and perhaps around Whangaroa, is probably connected with the displacement. If this is so, it seems fair to assume that the amount of disturbance and relative north-westward shift will decrease south-westwards, away from the intrusive mass and the supposed main plane of weakness. In other words, the curve of shift against distance from the intrusive will flatten out. We have not enough data to find out just how rapid this flattening out may be, but some estimate of it may be attempted. The average gradient of the curve over the whole distance between Waiari and the copper mine† is 77%. Between Waiari and the base of the breccia south-west of Brodie's Creek it is 72.5%, while between this last point and the copper mine it is 80%.

This flattening of the curve of shift against distance from the intrusion becomes of interest when the distribution of the rocks of Group 1 is examined in the light of the tear fault movements. Let us assume that, over a further 2,400 yards south-westwards of Waiari, the average gradient of the curve falls to 70%. This means that the breccia base at Waiari must be shifted 1,680 yards to S.40°E., relative to the outcrop of the pillow lavas near the northern end of Tokerau Beach. Then, restoring the breccia base north-east of Waiari to its original east-and-west disposition, and plotting the position of the pillow lavas 700 yards north of the breccia base south-west of Brodie's Creek, we find that a line joining the pillow lavas at Tokerau Beach and the new

* In calculating the amounts of these displacements the strike of the base of the breccia has been taken as being east-and-west. There is a suggestion, in the trend of the relatively long section of the basal contact exposed south-west of Homarere, that it may have been originally more nearly east by south, the effect of drag on the tear faults having affected, to some extent, the whole of the short sections of the beds between them. If this is so the gradient of shift must be greater.

† It must be realized that the position of the contact at the copper mine is only approximately known at present.

position of those of Brodie's Creek trends east by south (text-fig. 3). It will be recalled that the few data gained from the outcrops of the Group 1 lavas suggested a more or less east-and-west strike, with which the results of the present reconstruction harmonize quite well. Further comment on the significance of this zone of tear faulting is given in discussion of the associated intrusive rock (p. 55).



Text-fig. 3. Diagram showing the effects of tear faulting along south-east coast of Rangiawhia Peninsula.

Correlation of the pillow lavas at Tokerau Beach and Brodie's Creek implies the persistence of basic submarine lava-flows at roughly the same horizon for 7,000 yards along the strike. This demand will be the more readily granted for the fact that, as has already been mentioned, between Taipa Beach and Mangonui Township, on the opposite shore of Doubtless Bay, basic variolitic lavas, showing pillow structure and similar in many respects to those around Whatuwhiwhi, form a continuous east-and-west belt for at least 8,250 yards along the coast.

The strong folding about east-and-west axes recorded by the rocks of Group 3 supports the view that this fold-direction represents a trend of fundamental importance in the Far North.

Structural data on the region north of the Raetea and Maungataniwha Ranges, which extend west-south-west from south of Whangaroa Harbour to south of Kaitaia, are not numerous. Concerning the northern flank of the Maungataniwha Range, McKay (1894, p. 72) remarks that "the Cretaceo-tertiary rocks sweep round the older rocks in all directions and, except where contact is made along lines of fracture by faulting, are usually inclined at moderate angles." He records dips to the west and north-west at Peria (1894, p. 85).

Marshall, who made only a rapid traverse of the country, states (1908, p. 81) that a north or north-north-east strike "appears to be represented in the hills between Mangonui and Oruru Valley and in the shales that are occasionally displayed in the range extending from Reef Point to Raetea."

In the Whangaroa district, Bell and Clarke (1909, p. 42) found that their Waipapa Series, which they regarded as Palaeozoic or early Mesozoic in age, is folded into an anticlinorium that trends west-north-west and east-south-east on the eastern seaboard and east-north-east and west-south-west in the inland area. Dips range from 30° to vertical. The rocks of their Kaeo Series, of Cretaceous and Tertiary age, they found to have a very variable strike, but they concluded that in the southern area around Lake Omapere the strike is east-north-east and west-south-west, while in the area around Whangaroa it is meridional (p. 47).

Ongley (in Morgan, 1919, pp. 39-40) has supplied data on the attitudes of limestones in the Victoria Valley and near Kaitaia. His observations suggest a dominant south-eastward strike and moderate south-westward dips. One almost east-and-west strike with a steep southward dip and one north-east strike and north-westward dip are recorded.

To these observations must be added the fact that Cretaceous rocks strike east-and-west and dip northwards at angles from 30° to 70° for a mile across the strike in Taipa Estuary.

In the North Cape-Cape Reinga area more detailed information is available in the work of Hector (1872), McKay (1894), Bell and Clarke (1910), and Bartrum and Turner (1928). From this work it is clear that the lavas and sediments of the Rahia (Upper Cretaceous) Series, with which the Whangakea Series is now united (Bartrum, 1934), strike east-and-west or west-north-west and east-south-east with moderate to steep dips. In the lowest division of the Coal Point (Mid and Upper Tertiary) Beds Bartrum and Turner record prevailing southward dips, with which McKay's statement (1894, p. 72) agrees, but in the middle and upper divisions the dominant direction of dip is south-westward at angles of from 15° to 35°.

These observations seem to justify the conclusion that there exists an important development of post-Cretaceous folding about east-and-west axes in the region north of the latitude of Reef Point and the Bay of Islands which has not so far received much attention save from Bell and Clarke (1909) in their statements on the Waipapa Series and the southern area of the Kaeo Series.

To move into a more speculative field, it seems possible that there is some connection between this east-and-west folding and the trends of the Raetea and Maungataniwha Ranges; the high ground on Rangiawhia Peninsula, including Puheke; the North Cape-Cape Reinga block and the line of summits represented by the Three Kings Islands. Generally speaking, these areas have cores of hard rocks with Cretaceous and later sediments lying off them with, in many cases, northward and southward dips. When McKay (1894, p. 72) writes that "the Cretaceo-tertiary rocks sweep round the older rocks in all directions" it is possible that he is describing the effects on the attitude of the strata of axial culminations and depressions in a system of east-west folds.

It should be noted that Bartrum and Turner (1928, pp. 136-7) concluded that the evidence from North Cape supports the view that "fold-axes open out to the north and north-west of the main structural axis of New Zealand and pass through North Auckland as an integral part of [Suess's] 'Third Australian Arc.'" In reaching this conclusion they were influenced by the north-westward trend of the foliation in the gabbro of North Cape. The present study proves, however, that this gabbro, which must certainly be part of the same mass as that exposed in Rangiawhia Peninsula, was intruded under the influence of powerful north-westwardly directed shearing forces, to which its foliation may be ascribed, and that the intrusion and shearing were both later than the folding movements.

The mechanics of tear faulting have been dealt with by E. M. Anderson (1942, pp. 13-14 and Ch. V; see also Kennedy, 1946, pp. 67-70). Tear faults (transcurrent faults) theoretically should occur in two sets inclined at somewhat less than 45° to the direction of greatest pressure, the movements on one set being sinistral and on the other dextral. One or other of the two sets may in some cases be suppressed.

The trend (N.40°W.) of the tear faults in our area and the fact that the displacement on them is sinistral means that, to accord with Anderson's theory, the direction of greatest pressure must have been west by north and east by south. We are not dealing, therefore, with a system of folds and faults related to one direction of compressive force, like that so beautifully shown in South Wales (Anderson, 1942, p. 56). On the contrary, we must infer a change from north-south compression to east-west compression between the period of folding and the period of tear faulting. That such a change should take place within a relatively short span of time is surprising, but on the evidence available it seems that the idea must be entertained provisionally. The meridional strike found by Bell and Clarke (1909) in the northern area of their Kaeo Series may perhaps support the idea that such a change did take place.

There have been two main ideas about the structure of North Auckland. (1) The trend of the North Auckland Peninsula is not connected with the direction of fold axes, but is the result of a later system of fractures. This was the early view of Suess (II, p. 146) and was adhered to by Marshall (1908), Bell and Clarke (1909), Park (1921) and Benson (1924, pp. 128-132), though these geologists were not at one about the directions of fold axes. (2) The trend of the North Auckland Peninsula is the expression of a system of north-west trending folds. This was Suess's later view (IV, p. 318) and was held tentatively by Ferrar (1925, pp. 18, 33), more definitely by Bartrum and Turner (1928, pp. 136-7), and with considerable confidence by Macpherson (1946).

The study of Rangiawhia Peninsula supports the first of these conceptions and, more specifically, shows that the early folding there was about east-and-west axes and was presumably due to north-south compression, while it suggests that the later north-west fractures were due to east-west compression.

Enough is not known of the kind of displacement on the fault that brings black shales of Group 2 against beds of Group 3 for it to be definitely related to either of these two inferred systems of forces. The faulting took place before the north-westward tear faulting and probably after the east-west folding, for if the Group 3 beds are first unfolded an improbable flat-lying thrust must be invoked to explain the relations of the shales to the breccia group. The relative ages of the two sets of beds are not known with certainty, but from the appearance and degree of induration of the shale as compared with the breccias, conglomerates and sandstones, there can be little hesitation in pronouncing the shales the older. Where it meets the lavas of Group 1 near Homarere the fault hades 27° to the north-north-west. Evidence has already been given for the belief that the movement in the area mapped took place on two faults *en echelon*. If these are normal faults, a third system of forces is required to explain them. It seems more likely that they are related to one of the other sets of movements, in which case they are probably tear faults, and their behaviour where one of the planes meets the Group 1 lavas would suggest sinistral displacement, which would relate them to the epoch of north-south compression.

Age.

Nothing is known of the age of the shales of Group 2. From their indurated nature they are considered, without much doubt, to be older than the Group 3 beds.

In the absence of fossils and of descriptions of comparable beds elsewhere the age of the beds of Group 3 must also remain uncertain. Reasons have been given for the belief that the underlying rocks may be pre-Cretaceous, and it was there mentioned that the breccias, sandstones and conglomerates do not have a Tertiary aspect.

Conglomerates at the base of the Kaeo Series (Cretaceous and Tertiary) in the Whangaroa district contain pebbles up to 2 inches across of graphic granitic rocks (Bell and Clarke, 1909, p. 50), and pebbles of graphic granodiorite occur in Upper Cretaceous conglomerates on the southern shore of Hokianga Harbour (Mason, 1948). The large size of the masses of graphic granodiorite at Waiari, five or six feet across (plate 2, fig. 3), indicate that the terrain from which they came was close at hand. The presence of these boulders, together with the degree of consolidation and general field appearance of the grits and sandstones accompanying the conglomerates are virtually all the justification that exists for assigning to them an Upper Cretaceous age and regarding them as basal beds of the post-Hokonuian transgression. As there will be occasion to notice later, Bartrum (1934) correlates the intrusive of North Cape with the supposedly early Tertiary intrusives of Silverdale, near Auckland, and since the intrusives of Rangiawhia represent another portion of the North Cape mass, and cut the beds of Group 3, we have a tentative upper limit to the stratigraphical position of the latter and to the date of their folding.

GROUP 4.—INTRUSIVE IGNEOUS ROCKS.

Distribution.

As has already been mentioned, dykes of medium- to course-grained intermediate and basic igneous rock intrude the other solid formations in all parts of Rangiawhia Peninsula, but become more numerous and more massive eastwards, until they give place, around Whangatupere Bay, and in Cape Karikari, to a continuous mass of coarse-grained igneous rock.

The average trend of dykes is north-west by north, though those of a group in the headland east of Perehipe run more nearly north. With the exception of two dykes running east-and-west at the northern end of Tokerau Beach, the only other trend represented is between north-east by north and north-east by east near the contact of breccias and conglomerates of Group 3 with the lavas of Group 1 between Waiari and Brodie's Creek, and in the black shales, in which the intrusions are parallel with the parting.

The dykes are easily weathered and the sea has usually eroded them away to form north-west trending clefts and inlets along the coast. It may clearly be seen, as one proceeds eastward, how this grain gradually overmasters the general north-eastward trend of the south-eastern coast of the Peninsula and eventually becomes completely dominant and dictates the course of the coast-line at Whangatupere Bay and in Cape Karikari. Its influence, in reaction with the stubborn relics of the invaded country, produces the bipartite form of Matai Bay, an effect seen to even better advantage in the coastal morphology on both sides of Bergen's Point, at the south head of Doubtless Bay (Provisional One Mile Sheet N.7), and particularly in Taimaru Bay and the charming little trefoil indentation of Waimahana Bay.

In the deep, narrow bay 1,000 yards south-west of Brodie's Creek the pinnacles of rock arranged along north-west lines, which break the surface of the water, are masses of country rock resisting the sea after the intrusive rock that formerly enclosed them has been driven back a furlong to the north-west.

The south-western shore of Whangatupere Bay is composed almost wholly of intrusive rock with only small amounts of included hornfelsic country rock. In the ridges leading to the headlands of Knuckle Point and Pihakoa remnants of the roof of the intrusive are preserved in the form of metamorphosed lavas and sediments of Group 1, invaded by a swarm of dykes springing from the intrusive mass below. Quite large masses of country rock continue down to sea level at the north-western and south-eastern ends of Whangatupere Bay.

The western margin of the intrusion cannot be investigated along much of its length for lack of outcrops, but it probably does not possess a mappable boundary, passing rather, by increase in the amount of included rock, into a swarm of dykes, as for example in Maitai Pa* (plate 3, fig. 1) and the north-western corner of Matai Bay.

The rock composing the intrusion is petrographically very variable. It ranges from leucocratic types well seen in the two bluffs on the southern shore of Matai Bay to melanocratic rocks near the north-western end of Whangatupere Bay and in Cape Karikari. The various types have not yet been petrographically examined, but in the hand-specimen they are seen to include light- and dark-coloured diorites,

* The cusp in the centre of Matai Bay.

gabbros, pyroxenites and greenish, porphyritic, uralitized or chloritized andesites which appear to invade the other rocks in irregular dyke-like masses. Narrow veins of a fine-grained rock with a very small proportion of dark constituents traverse the complex. The contacts between the different rock types are sometimes sharp, sometimes gradational; they run straight for only short distances in most cases, but their general trend is between north and north-west.

The dykes west of the main intrusive mass are mostly andesites and porphyritic micro-diorites.

In the main mass at Whangatupere Bay there is a well developed joint pattern with one set of vertical joints, along which there has been intense shearing, running N.30°W. to N.40°W., and another set roughly at right angles to this, while a more or less horizontal sheeting characterizes the rocks exposed along the coast. The joints cross all types of rock in the complex indifferently.

The Rangiawhia intrusion strikes directly towards the massif of ultrabasic and basic rocks that forms North Cape and Kerr Point, in which there is a foliation trending steadily north-west and south-east in conformity with the strike of the south-western margin of the mass (Bartrum and Turner, 1928, p. 123 and map, p. 99). The gabbro at Whangatupere Bay and Cape Karikari is very similar in hand specimen and field occurrence to that exposed on the shore of the bay on the southern side of North Cape, and due west of the lighthouse, where leucocratic veins and hornfelsic inclusions like those at Whangatupere Bay are to be found. No peridotites, however, have been recognized in Rangiawhia Peninsula. Since Bartrum and Turner (1928, p. 121) remark that gabbroic rocks intrude the ultrabasics at North Cape particularly on the western margin of the massif, it is possible that peridotites lie off shore north-east of the coast at Rangiawhia Peninsula. On the other hand, it seems that there is a greater proportion of leucocratic rock-types exposed in Rangiawhia Peninsula, while biotite, which is not recorded in the descriptions of North Cape rocks, is conspicuous in the diorites and some of the gabbros at Rangiawhia. This, together with the preservation of part of the roof of the intrusion there, suggests that in the south-east we have exposed the upper part of the plutonic mass, which rose to a higher level in the crust at North Cape, where its deeper parts are now visible. The fact that much coarser-grained rocks (with crystals up to four inches across) are described from North Cape than any yet found at Rangiawhia may support this idea. Petrographic study of the rocks should throw more light on the question.

South-eastward, the Rangiawhia mass strikes towards Bergen's Point and thence to the intrusive mass of gabbro, diabase, diorite and andesite of post-Waipapa (Palaeozoic-early Mesozoic) and probably post-Kaeo (Upper Cretaceous-Tertiary) age mapped by Bell and Clarke (1909, pp. 76-7) around Haunga trig. station south-south-west of Kaeo. Little is recorded of the grain of the intrusive body here, but the rock types are the same as those to the north-west, and the copper mineralization associated with them provides a link with the Rangiawhia rocks.

It seems very likely that they should be regarded as part of the same great dyke-like mass*.

The correlation of the intrusions along the line between North Cape and Haunga implies that the tectonic environment and style of faulting so intimately linked with it at Rangiawhia probably prevails over the same distance. Bartrum and Turner (1928, p. 104) infer that the south-west side of the North Cape mass is faulted, and Bell and Clarke (1909, p. 80, etc.) emphasize that the country of the Pupuke copper mines around Haunga is much faulted.

This belt of intrusion and inferred faulting, from North Cape to Haunga, is probably part of a very much larger tectonic element, for, when its line is continued south-east of Haunga beneath the Kerikeri basalt flows, it emerges to run accurately along the south-western margin of the basement rock (here mapped as greywacke and argillite) from near Puketona to the western side of the Waiomio depression†. Recent discoveries by the Geological Survey have invested the line along the south-western margin of the greywacke from Waiomio to Whangarei (where it joins the Harbour Fault of Ferrar, 1925, p. 18) with very great tectonic importance‡. The details of this work are eagerly awaited, for it now seems that a line from North Cape to Whangarei Harbour mouth may be expected to prove of great significance in North Auckland structural interpretation.

Age of the intrusion and associated faulting.

Bartrum (1934), after incorporating the Whangakea Series of the older maps of the North Cape area in the Upper Cretaceous Rahia Series, pointed out that the North Cape gabbro and ultrabasic rocks must consequently be regarded as having been intruded during the orogeny that closed upper Cretaceous sedimentation in that area. He correlated them with the supposedly early Tertiary serpentine intrusions in the Silverdale district near Auckland.

It does not now seem necessary to suppose that the intrusion was connected with the folding movements that closed the Cretaceous and and early Tertiary sedimentation; rather seems it to have been connected with a quite different and later scheme of movements. When more is known of the age of the rocks of the Kaeo Series invaded by gabbros and diorites near Whangaroa Harbour it will be possible to give a more satisfactory maximum age for the intrusion and faulting. As for its minimum age, there are intrusions in the lowest division of the Tertiary beds near North Cape that might not unreasonably be supposed to be a product of the North Cape intrusive episode, though Bartrum and Turner who described them (1928, p. 127) did not regard them as such. If they are connected with the North Cape mass the period of intrusion and faulting is at least as late as lower Miocene.

* There are similar rocks between Tupo Bay and Taupo Bay north-west of the entrance to Whangaroa Harbour and five miles north-east of the strike line through North Cape, Cape Karikari and Haunga, which may be genetically connected with the same intrusive system.

† A narrow tongue of basement rock crosses this line on the northern side of Ngapipito Valley owing to the upthrow on the northern side of the Kawakawa Fault.

‡ Personal communication from Mr. R. Hay.

All this remains speculative at present. All that can be said with certainty is that the whole episode of intrusion and faulting was post-Cretaceous.

5.—DRIFTS.

(a) *Elevated marine sands.*

A flat bench some 250 yards broad, a trifle under 100 feet above sea level and sloping inland slightly, fronts the coast between Waiari and Brodie's Creek. Subaerial erosion by a swampy streamlet that runs south-westward along its inland margin and collects the run-off from the high ground to the north has caused it to decline towards Waiari. The same surface may be seen around the Hall at Whatuwhiwhi and again north of the school-house, where it is 120 feet above sea level. Farther west it is represented in the flat tops of the spurs between Patia Beach and Perehipe (135 feet) and between Perehipe and Tokerau Beach (150 feet). Thence it skirts the western end of the Te Ari Ridge above the Tokerau Beach-Merita Road. In all these places it is underlain by sands which, to judge from the cuttings along the road, are about 70 feet thick on the spur between Tokerau Beach and Perehipe, though they are much thinner to the east, for only about 10 feet of them can be seen from the shore in the edge of the bench north-east of Waiari.

The schoolmaster's house at Whatuwhiwhi stands on a remnant of a subordinate flat bench 50 feet above sea level.

Sands cover the surface around the eastern end of the Te Ari Ridge, between Brodie's Creek and Merita, to a height of 195 feet, and they sweep up the northern flank of the ridge to about the same height along its whole length. The tops of the spurs are fairly flat for 1,500 yards south of Merita village—that is, to just below the 200-foot contour —where the ascent of the main east-and-west ridge begins and the sandy soil gives place to clay, but the break of slope is not very sharp and the upper limit of the sands can be fixed only roughly.

East and north-east of Merita the sands probably extend to about the 200-foot contour also (plate 3, fig. 1). The neck of land between Matai Bay and Karikari Bay is composed of them and they lap on to the slopes of the high ground along the eastern side of Cape Karikari.

Behind the little bay on the western side of the Cape, two terraces are well developed; the more prominent one is a little more than 100 feet above sea level, backed by low rolling downs to 200 feet, and the other is at about half this height. These two surfaces accord with those developed around Whatuwhiwhi. The 100-foot level is also represented above the cliffs of consolidated sand at the eastern end of Karikari Beach.

The sands vary in thickness. At the eastern end of Karikari Beach they extend to sea level, or below, while between the road and Matai Bay they are exposed almost to sea level and enclose well-preserved logs of wood and stumps of small trees. Northward, however, the sand capping the bluffs at the back of the northern half of Matai Bay can be seen feathering out against the slopes of the hill at the northern head of the bay.

It seems from the gradual decrease in the height of the coastal bench east of Tokerau Beach that a slight tilting downwards to the east accompanied, or followed, the change of sea-level. To explain the facts that the sands extend higher on the northern face of the Te Ari Ridge than on the south and that there is no definite break of slope at their upper limit, it may be suggested that more sand was supplied to the north-western coast and that wind-borne sand was swept up the shore above tide-mark there, whereas the well-marked bench on the southern and south-eastern coast shows the true level of the strand, as does the sand surface deposited just off the old shore around the eastern end of Karikari Beach and on the western side of Cape Karikari. The rolling surface, rising to 200 feet between the upper bench in this last area and the higher ground to the east, may represent old sand dunes behind the 100-foot shore.

The "100-foot" level* has not previously been recorded in the Far north (Henderson, 1924, pp. 582-3) but is well known along other parts of the New Zealand coast from the Auckland district southward and belongs to a period of erosion called by Henderson the Awakino Cycle (1924, p. 589). The 50-foot level represents a later, less prolonged period of steady sea level and may, perhaps, be linked with an erosion level of about this height near Whangarei (*ibid.*, p. 582).

(b) *Sand dunes* and (c) *Alluvium.*

The shifting and partly fixed sand dunes that form belts along the shores of the tombolo joining Rangiawhia Block to the mainland, the fixed dunes of its central part and the swamps impounded by the active dunes against the fixed ones will not be considered here.

On Rangiawhia Block itself small foredunes lie behind the beaches at Perehipe, Patia, Whakarara and the little bay west of Cape Karikari. A small alluvial bay-head filling lies behind the dunes of Patia and Whakarara, joining the headland at Patia Pa to the land on the north, and a small area of alluvium occupies the valley behind the dunes at Cape Karikari. These flats form an insignificant proportion of the land surface but are important in the farming economy of the Maori population.

SUMMARY.

The following conclusions can be drawn from the geological mapping of Rangiawhia Peninsula to date:

Igneous rocks of the spilitic suite, including basic pillow lavas and keratophyres, were poured out on the sea floor, and partly intruded into the muds and muddy sandstones accumulating there, probably in late Palaeozoic or early Mesozoic times. Such eruptions, it seems, took place over a wide area, the sequence of events at the Three Kings Islands being closely comparable with that at Rangiawhia.

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* Probably a little more than 100 feet on the average.

Little is known of the structure of these rocks, or of the earth-movements that followed their formation, but an east-and-west strike appears to prevail in them now. If the basic pillow lavas be accepted as of one horizon, their distribution offers some hope for the future elucidation of this phase. Perhaps granodiorites were intruded then. Whether they are of this age or older, they were exposed by erosion of the land that existed after the movements.

Succeeding submergence of a steep coastline crossing the area led to the formation of a great boulder beach over which grits and sandstones and probably a pile of other sediments were laid down as the waters deepened. This submergence possibly took place in Cretaceous times.

Violent folding about east-and-west axes followed this sedimentation and bent the strata to a vertical attitude. After the folding—perhaps as a later phase of the same movement, or long after—the crust broke along a fracture system running east-north-east along the south-eastern margin of the present Peninsula and the area to the south was displaced relatively to that on the north, so that shales of some lower formation were brought against the boulder beds and sandstones. The failure to find fossils to establish the age of the formations involved in this phase restricts severely the interpretation of the geological history.

Later still, in post-Cretaceous times, that part of the crust lying north-east of the area was wrenched north-westward for a distance of some miles, part of the displacement being accounted for by movements along a system of closely-spaced tear faults that runs north-westward across the present Peninsula and probably extends a long way to the north-west, through North Cape and to the south-east past Whangaroa, beyond which it may link with an important line of displacement that continues to Whangarei Harbour.

At the same time a long belt of intrusive basic and intermediate igneous rocks with numerous small offshoots was injected along the plane of movement over a distance of some 70 miles.

Subsequent small movements of sea level in comparatively recent times are recorded by elevated marine terraces and sands.

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PLATE 1.

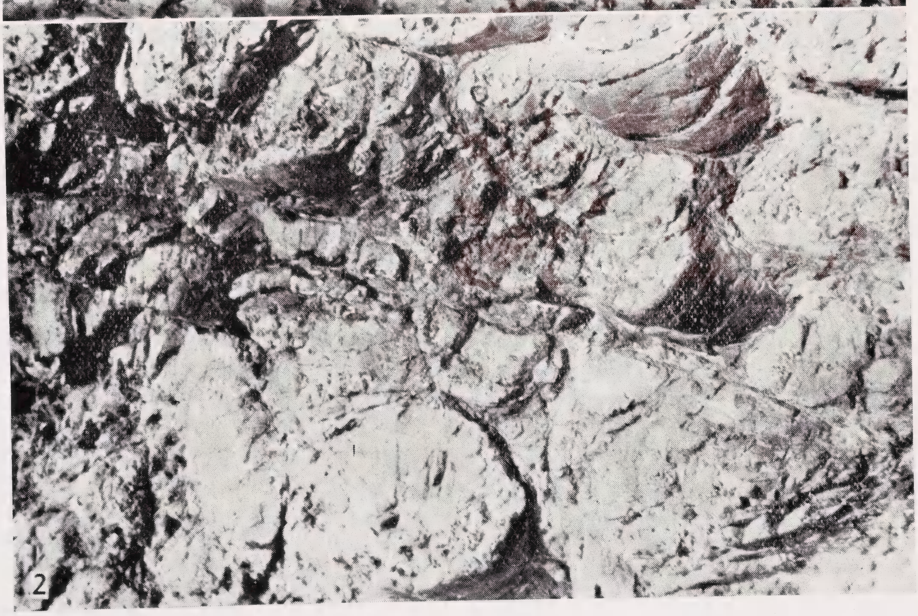


Fig. 1. Pillow lavas 600 yards SSW. of Brodie's Creek. The formation dips 66° to the left (S. by W.).

Fig. 2. Closer view of pillow lavas SSW. of Brodie's Creek. There is hardly any sedimentary material between the pillows here: the interstitial rock is glassy lava.

Fig. 1. Fine conglomerates, grits and sandstones at Waiari. Shales outcrop at extreme low tide mark at the upper left corner of the photograph.

Fig. 2. Breccia-conglomerates overturned and cut by a slightly transgressive sill 250 yards NE. of Homarere. Shales are faulted against them 18 yards to left of bluff.

Fig. 3. Boulders of graphic granodiorite weathered from conglomerate 100 yards N. of headland at Waiari. Beds containing them are 150 feet below those of Fig. 1.

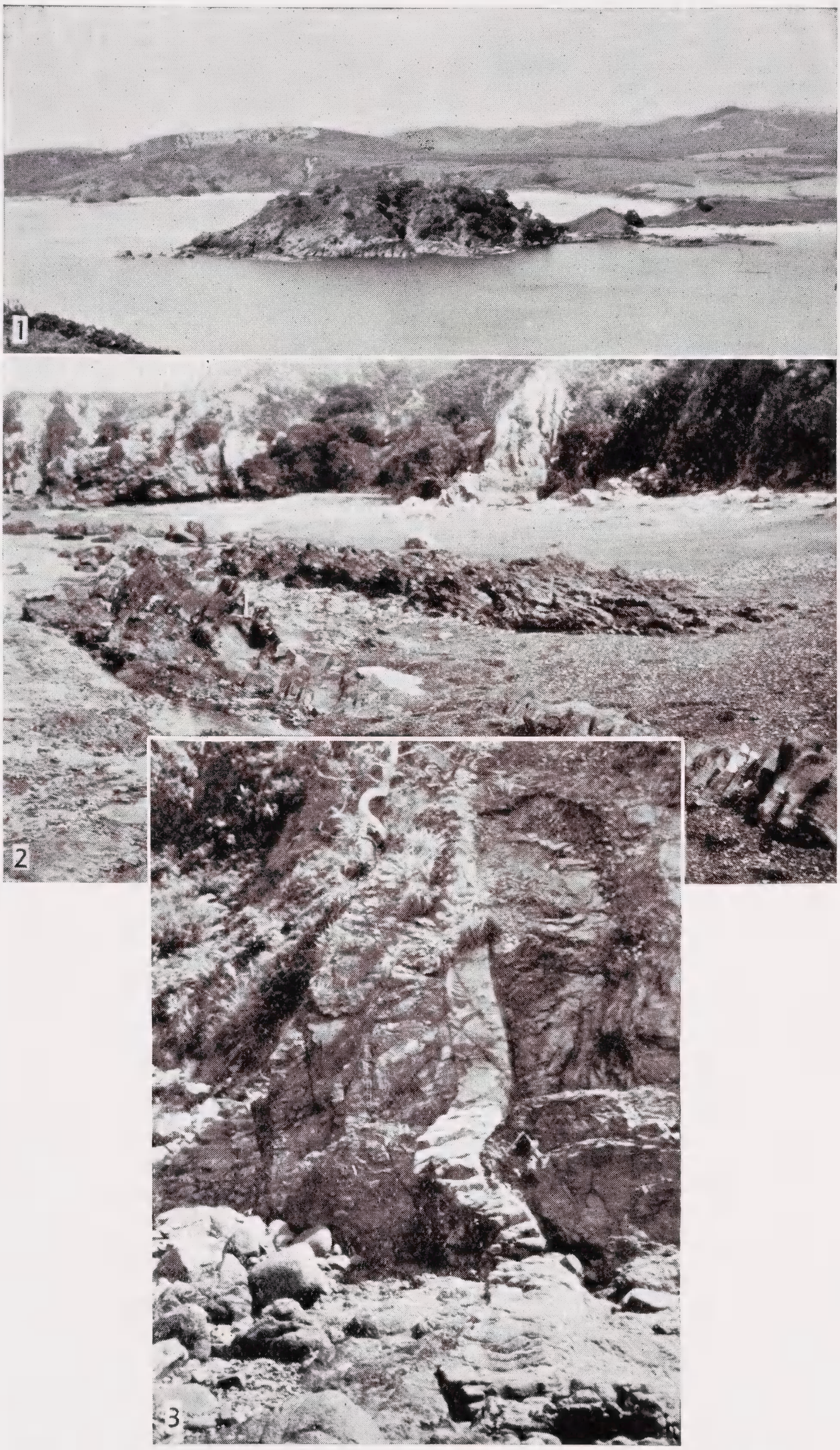
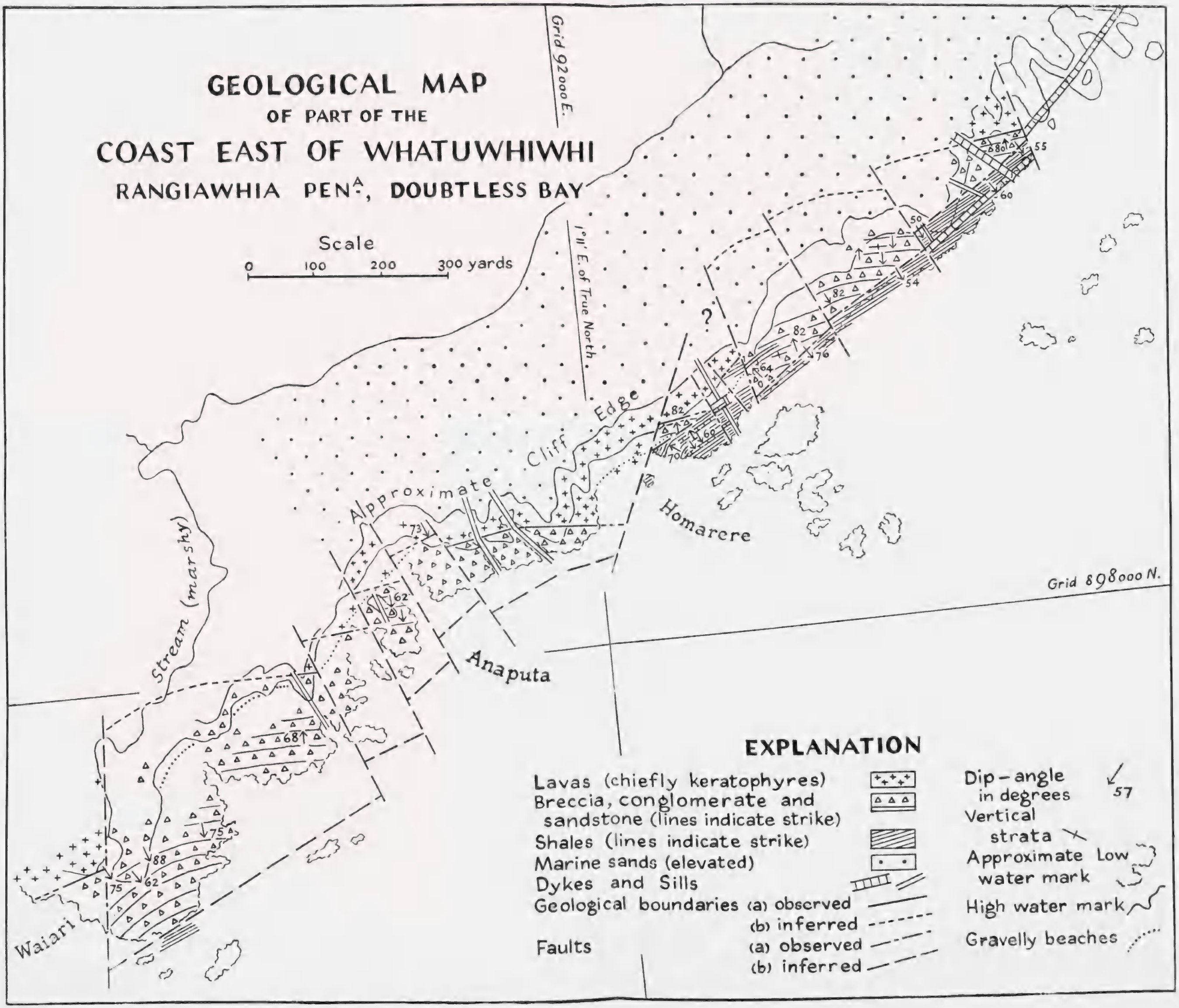


Fig. 1. Matai Bay looking S. NW. grain in Maitai Pa (centre) due to dyke intrusion and shearing. 200 feet sand surface behind right end of Pa.

Fig. 2. Black shales at Homarere. Hammer rests on sill. Keratophyres in cliffs. Between the two is a patch of breccia beyond right edge of photo. Flat top of cliffs is 100 feet marine terrace.

Fig. 3. Dyke cutting black shales 550 yards NE. of Homarere.


GEOLOGICAL MAP
OF PART OF THE
COAST EAST OF WHATUWHIWHI
RANGIAWHIA PEN^A., DOUBTLESS BAY
Scale
0 100 200 300 yards
Grid 92000 E.
1°11' E. of True North
Grid 898000 N.
Approximate Cliff Edge
Stream (marshy)
Anaputa
Homarere
Waiari
EXPLANATION
Lavas (chiefly keratophyres)
Breccia, conglomerate and sandstone (lines indicate strike)
Shales (lines indicate strike)
Marine sands (elevated)
Dykes and Sills
Geological boundaries (a) observed
(b) inferred
Faults (a) observed
(b) inferred
Dip-angle in degrees 57
Vertical strata
Approximate Low water mark
High water mark
Gravelly beaches

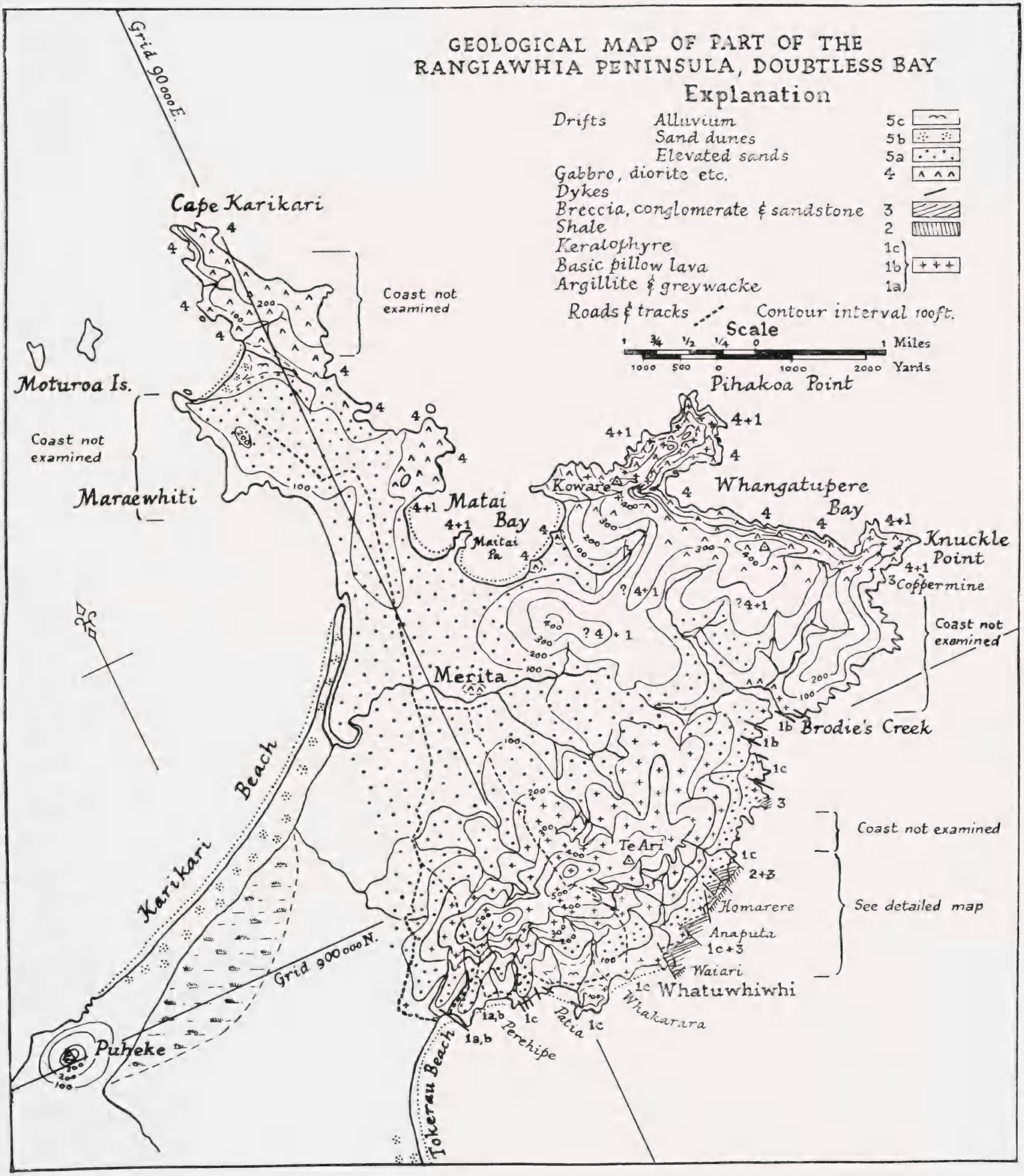

GEOLOGICAL MAP OF PART OF THE
RANGIAWHIA PENINSULA, DOUBTLESS BAY
Explanation
Drifts
Alluvium 5c
Sand dunes 5b
Elevated sands 5a
Gabbro, diorite etc. 4
Dykes
Breccia, conglomerate & sandstone 3
Shale 2
Keratophyre 1c
Basic pillow lava 1b
Argillite & greywacke 1a
Roads & tracks
Contour interval 100ft.
Scale
1 3/4 1/2 1/4 0 1 Miles
1000 500 0 1000 2000 Yards
Grid 90000E.
Grid 900000N.
Cape Karikari
Coast not examined
Moturoa Is.
Maraewhiti
Matai Bay
Maitai Pa
Pihakoa Point
Koware
Whangatupere Bay
Knuckle Point
Coppermine
Merita
Brodie's Creek
Te Ari
Homarere
Anaputa
Waiari
Whatuwhiwhi
Whakarara
Patia
Perehipe
Tokerau Beach
Karikari Beach
Puheke
See detailed map

PLATE 5.